

# **An Integrated Hospital Information System at Children's Hospital**

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## **ABSTRACT**

In late 1986, Children's Hospital set out to design and implement an Integrated Hospital Information System ("IHIS") by interfacing licensed departmental applications to each other and to a set of centralized database tools. Although systems integration strategies and "open" systems are much discussed, relatively few large scale implementations of this style have been attempted. A three year plan and budget were approved in October 1987, and at this writing, the project is nearing completion. This report and companion papers [2-7] describe the current status of this effort and highlight certain issues attendant to this approach.

## **BACKGROUND**

In the mid 1980s, a consensus emerged among institutional planners at Children's that clinical, fiscal, and administrative advantages would accrue to patients and to the organization by investing in information technologies. The benefits expected by clinicians included reduced time to collect diagnostic results, improved communications among the extended care team, and improved access to medical knowledge in the context of clinical planning. Administrators expected automation to contain or reduce costs in certain areas, to improve communications within the organization, and to strengthen the institution's ability to plan and respond during changing financial times. The planned capstone application of the IHIS was committed to be a Progressively Automated Medical Record ("PAMR").

Much attention has been paid in commercial and academic contexts to the features of applications which could replace, in whole or in part, the patient's medical record. Many have described the benefits (both anticipated and realized) of an automated patient chart [see refs in 1, 8-9]. The major limitations of a paper-based medical record (frequently inaccessible, incomplete, or illegible; often poorly organized or redundant; costly to create, maintain, store, retrieve, and analyze) have driven efforts to automate the chart. However, obstacles to such efforts have been formidable. The chart is an object which is deeply familiar to its users. A variety of strategies are used by the skilled reader to find a particular fact or to understand the patient's overall clinical course. When available and complete, a paper-based medical record is a valued and familiar tool for clinical planning and communications. The familiarity of the paper-based medical record notwithstanding, one of the goals at Children's has been to gradually replace the paper-based record with a computer based medical record.

With this end in mind, a review of approaches toward implementing an IHIS identified a few strategies, including:

- (1) licensing a complete hospital information system from a single major vendor;
- (2) authoring a complete hospital information system using either MUMPS [11] or other toolsets [12]; or
- (3) licensing diverse departmental systems and

seeking to integrate these departmental systems into an institutional system.

Planners at Children's found option #1 lacking because no existing complete hospital information system (commercial or academic in origin) could satisfy the needs (or strongly held beliefs) of the spectrum of users within our hospital community. The time, expense, risk, and complexity of authoring a complete hospital information system from first principles (option #2) were viewed to be prohibitive. Option #3 was selected [1]. We concluded that departmental applications could be licensed at reasonable cost from reliable vendors, and that these applications would satisfy most users while addressing architectural concerns necessary to achieve systems integration.

Previously, systems assembled using this approach have had certain substantial limitations, including:

- (1) the absence of a single institutional database, with resulting duplication of data entry, dissynchronization of data elements, and difficulty in cross-departmental data display;
- (2) operational complexities of managing diverse hardware and software platforms;
- (3) variable quality and stability of commercial vendors;
- (4) absence of mature departmental applications in several important domains, including medical records, nurse care planning, and clinical orders;
- (5) absence of a single user interface and common command language for users, especially clinicians, who need access to diverse departmental systems.

These prior limitations notwithstanding, we set out to license departmental applications and apply systems integration techniques to mitigate some of these problems. It was clear that application-to-application interfacing approaches (e.g. Simborg [13], and, over time, HL7 and MEDIX) could create synchronization of certain key ("core") data elements. Further, commercial applications could be licensed (e.g., Simborg's STATlan) to provide network based, virtual terminal access to departmental applications. However, the virtual session approach did not create an institutional database, did not support automated patient records applications, and did not support rule based critiquing applications. We concluded that virtual terminal services to underlying departmental systems would not replicate enough of the functions of a chart to be considered adequate to clinicians. Tighter systems integration would be required.

There are different degrees of systems integration in healthcare. For some, an "integrated" HIS means merely net-based virtual terminal connectivity to departmental applications. To others, "IHIS" indicates application-to-application exchange of a core data element set. For us, the goal of systems integration is the same degree of data availability that is achieved by an architecturally homogenous system (commercial or locally authored [10-11]). We also sought the ability to include a wide variety of data structures, including full text, images, and voice.

To achieve this degree of integration requires a centralized database that either points to or replicates major subsets of departmental data necessary to create cross-departmental views and applications (the "virtual database" [2]). We determined that the technology and standards existed, or would be available shortly, to integrate departmental applications into an institutional database, thus preserving some of the advantages of single vendor and locally authored hospital information systems. Finally, we realized that the complexity and somewhat abstract nature of this project would require specific managerial tactics and practices to assure the requisite time, good will, and financial support necessary to implement such a system.

## IMPLEMENTATION PHASES

This project has been pursued in phases. During the first phase, we sought to provide connectivity among locations, devices, applications, and tools. During the next phase, we implemented licensed departmental applications to create the departmental data infrastructure. Concurrently, we acquired tools and techniques to create a virtual database from the amalgam of distributed departmental databases. During the current phase of this effort, we are focusing on systems integration of these departmental applications. Efforts now focus on creating workstation based synthesis applications which will replace high level functions such as the patient's record, clinical orders, and quality assurance by transaction review.

### Phase 1 -- Connectivity -- the physical infrastructure:

During this phase, we installed an institution-wide network consisting of parallel ethernets linked by bridges and centralized network management tools. Nearly 4000 wall jacks were cabled in a standard manner, and external gateways to wide area networks

were designed. Security systems were designed with the intention of supporting remote dialup access. All major computers and most personal computers are now on the network.

#### Phase 2 -- Departmental applications -- the data infrastructure:

Table 1 provides a list of many major departmental applications that were licensed and installed during this phase of the effort and indicates the major types of interfaces that are supported to provide for application to application data exchange.

APPLICATION	VENDOR	O.S.	USERS	INTER FACES
Patient Registration	Ferranti	VMS	100	A,T
Patient Billing	Ferranti	VMS	75	A,T
Pharmacy	Digimedics	UNIX	30	A
Clinical Labs	Cerner	VMS	300	A
Procedural Labs	Cerner	VMS	50	A
Nutrition	Computrition	UNIX	12	
Radiology	DMI	MUMPS	75	A
PACS (XRay Archiving)	Commview	UNIX	30	A
General Ledger	Walker	MVS	10	A,T
Accounts Payable	DDA	VSE	15	A
Case Mix Analysis	HBO	VMS	6	A,T
Email, Office Automation	Digital (Allin1)	VMS	3000	A
Nurse Staffing	Anso	PCDOS	10	
Materials Handling	Enterprise	PCDOS	10	A
Clinical Orders	Cerner	VMS	200	A
Clinic Scheduler	Pentamotion	VMS	125	A
Medical Records Management	Ferranti	VMS	40	A

1. **Interfaces:** A=Application to application via net broadcast; T=Tape;
2. **Users** include primary departmental users only.

Table 1: Major Departmental Applications and Interfaces

Certain interesting usage and cost parameters of this system include:

(1) During peak usage, approximately 700-800 simultaneous users are creating 1000 simultaneous VAX processes and interacting with 25-30 different applications.

(2) Approximately 1200 terminals, 350 personal computers, and 175 printers are attached to the network.

(3) Computing resources totalling approximately 100 MIPS of processing and 90 GB of magnetic storage (neglecting workstation based storage and personal computer-based MIPS and storage) are 80% utilized at peak load. A single optical jukebox with approximately 650 GBs is also used for live storage and archiving.

(4) Approximately 1000 laboratory lookups and 200 bibliographic searches are done per day on the network.

(5) The system installed at Children's can be replicated for approximately \$10,000,000. Total operating expenses are 2.1% of the institution's budget.

#### Phase 3 -- Systems Integration, a Virtual Database, and the Clinician's Workstation:

During this final phase of the project, efforts have focused on creating high quality interfaces between departmental systems and a set of centralized database tools. Specific tools have been selected to manage structured transactions using a relational model [5], to manage text document creation, handling, and retrieval [4,7], and to store and retrieve images and compound documents. Several advanced prototypes have been created to display clinical data on a bitmapped version of the patient's electronic medical record [2].

### ATTENDANT ISSUES

Many design and management issues have emerged during this project. This systems integration experience has provided a "time sliced" sampling of today's information technology issues. Some of the issues of interest include: the virtual database concept, database techniques, selection of graphic user interface tools, security considerations, clinical word processing, and use of expert systems technologies to critique clinical transactions.

#### The Virtual Database Concept

The problem of integrating multiple databases has been considered for several years. Several conceptual solutions have been offered [10], and commercial tools

are now available which interpose a software layer between multiple underlying data structures and databases and the application developer.

Regardless of toolset selected, it is necessary to distinguish between "core" data elements and other data elements. Core data elements are those relatively few elements that need to be shared by diverse ancillary systems [13]. It is not currently possible to achieve general purpose, application-to-application broadcast of all data elements. We have licensed or developed interfaces which partially replicate data originating in departmental applications into a centralized database [5]. The central database permits the assembly of a progressively automated medical record from the outputs of departmental systems and supports newly authored (central database dependant) applications.

Particular care is required to maintain the integrity of data elements in the institutional database. Since departmental systems will invariably have data dissonance (when a data element is common to two departmental systems but not contained in the core data broadcast), careful data dictionary practices are necessary to coordinate the inherent dissonance among departmental system data element values.

It is worth noting that techniques for automatically synchronizing core data elements need to address the same concerns that are raised in any multiuser application development environment (e.g., data integrity, security, synchronization, and recovery). Current (and near term) limitations in application-to-application broadcast techniques and the more general statement of the distributed update problem require compromises among data currency, data integrity, and interface complexity.

#### **Database techniques: Use of multimodal database tools**

A Progressively Automated Medical record requires support of digitized image and voice data structures as well as text and structured data transactions. The emerging concept of a compound document architecture is quite useful in the effort to implement a progressively automated patient record that includes a subset of diagnostic images. The compound document is more inherently similar to a medical record than preexisting file or record structures. A compound document can include diverse data types and sources, including digitized handwriting, unstructured text, linked text, formatted (static) tables, dynamic tables, and embedded SQL queries. A compound document can be inverted and retrieved by a text searching engine or hierarchically

indexed. The degree of independence of document from overlying application or underlying hardware is substantial. We have begun to deploy X terminals and X terminal emulators to selected locations to support compound document display. Preexisting terminals can display the non-graphic portions of compound documents clearly.

It may prove expedient to represent the same data differently as the data ages. User requirements and query patterns may suggest the use of an extended relational model for newer data and a compound document data structure indexed via an inverted list engine for older data. Some retrieval strategies (particularly of aged data) may be best supported by a text search on the inverted list version of a compound document. We are currently evaluating the kinetics of this transition to determine at what point the relational model ("the looseleaf chart") is converted into the inverted, compound document format ("the bound chart").

#### **Selection of Graphic User Interface Tools:**

The emergence of a variety of graphic user interface environments and toolsets creates both opportunities and new conundrums. We are porting our VT oriented PAMR applications to an X based environment after expending substantial efforts to balance the features of various environments (ease of use, cost, power, efficiency, and portability) and best guesses concerning emerging trends and standards.

#### **Security considerations -- Balancing access to data and protection of confidentiality**

Detailed policies and practices have been established to manage the tension between opportunities for ubiquitous access to data and requirements of confidentiality of patient care information. These policies are described elsewhere [13] and are available upon request.

#### **Clinician Word Processing**

Applications have been written which integrate a popular word processor into a document life cycle to permit the use of net-based word processing by clinicians to document patient care encounters [4]. This approach permits lower training costs and higher quality user interfaces.

## Use of rule-based critiquing system on a virtual database

The environment described here has proven to be a fertile context for authoring rule based critiquing systems using commercially available tools [6]. Real time, high volume critiquing of net-based clinical transactions may be the most interesting research opportunity created by the IHIS environment at Children's.

## SUMMARY

This experience demonstrates the feasibility of implementing a hospital information system using systems integration techniques. The resulting environment has many of the better features of central databased applications while permitting departments' substantial control over the choice of departmental computing environments. A progressively automated medical record and rule based critiquing system can be implemented as an overlay on a virtual database and a catalog of departmental applications. Continued evolution of tools and standards are likely to further reduce the complexity, costs, and risks of this approach.

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